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From Malthus to sustainable energy—Theoretical orientations to reforming the energy sector

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ABSTRACT

The main purpose of this article is to consider macro level theories for understanding the urge for reform as well as the process of societal change both in general terms, and more specifically within the energy sector. The aim is also to consider the energy sector in a wider context and analyse its recent development as a potential part of this reform. The scope and logical framework of this article is the following: The state of the global environment is approaching a point where the whole of humankind is in danger. The article reviews and discusses humankind's limits of existence and dialectics of the human–nature relationship by contrasting Malthusian and Boserupian theoretical views. This creates both practical and scientific needs. The long societal process of change is discussed according to the three-layer (3L) model of societal chance.

The production of energy has traditionally been one of the core issues concerning the effect humankind has on the environment, and with regards to potential change related to it, reforming the energy sector is in a key position. This article reviews and discusses the way the already established renewal of the energy sector corresponds to the 3L model, and the diverse potentials of the anticipated further progress.

Contents

1. Introduction

> "Man must stop pollution and conserve his resources, not merely to enhance existence but to save the race from intolerable deterioration and possible extinction." New York Times editorial, the day after the first Earth Day 1970.

Environmentalism became a popular and global discourse already in the 1960s, and the basic ideas and claims of modern environmentalism were presented half a century ago. The ideology of natural parks and nature conservation already had a long history back then, dating back to the latter half of the 1800s. The

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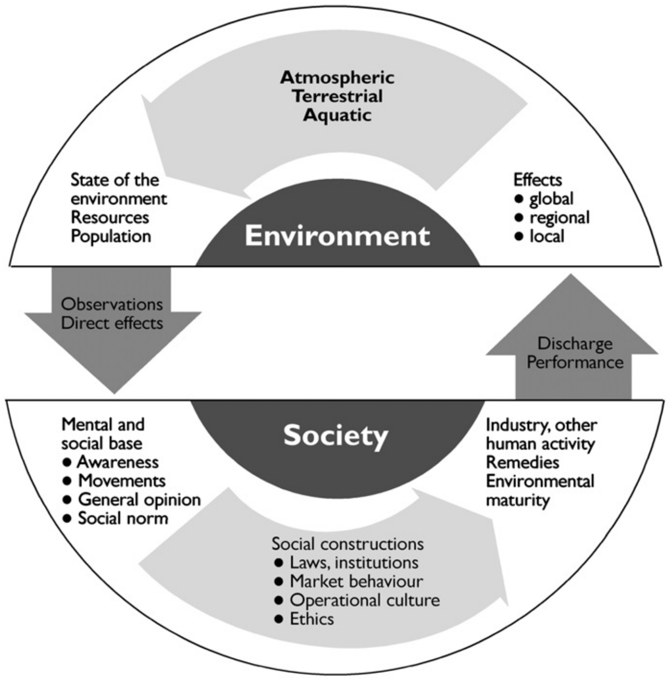

Fig. 1. Dynamics between the environment and society.

real wakeup calls were, however, the classical works by Rachel Carson (*Silent Spring*, 1962) and Barry Commoner (*Science and Survival*, 1966; *The Closing Circle*, 1971), accompanied by a number of famous writings by, for instance, the ecologists Garret Hardin (*The Tragedy of the Commons*, 1968) and Paul Ehrlich (*The Population Bomb*, 1968), David Pimentel, Howard Odum, John Steinhart, George Woodwell, Kenneth Boulding and Herman Daly to name a few American authors [1]. The main ideas were crystallised in *The Limits to Growth* [2].

These texts were followed by writings, debates and discourses about industrialisation, pollution and even "doomsday prophecies". In the course of its over a hundred-year history, environmental protection has developed from an issue promoted by single separate thinkers to general environmental consciousness and from the ideology of national parks towards sustainable development and the ecological modernisation e.g., [3] of society. There has been a shift from the protection of areas towards an active environmental policy and a shift from ideology towards a new practice e.g., [4,5].

Strong waves of environmentalism swept over societies across the world, and the idea of pollution prevention and nature protection became more generally accepted. The success of the environment theme resulted in new societal demands and reactions, for instance the establishment of the official environmental protection administration, and the ideology of sustainable development.

Environmental damage and overexploitation of natural resources have been observed, modelled and documented intensively, including in official statistics since the early days of environmentalism e.g., [6–13]. In present day discourse, the main problems are crystallised in the problematic of climate change [14], preceded by discussions and concerns that concentrated on pollution problems mainly from the 1960s and acidification from the 1980s [15]. However, all these are details within a more comprehensive whole of a general unsustainable way of living of human beings.

Writings and discussions about the scarcity of resources and sustenance base, and the survival of humankind decreased, even disappeared, sometime in the early 1990s, as new large oil reserves continued to be found. There have been different views and opinions at different times, depending on the specifics of each situation. New oil reserves moved the problems aside. However, lately the issue has become topical again: "*The world today faces enormous problems related to population and resources*" [1], and "*… the world is facing so many challenges that a paradigm shift is needed, and this will inevitably include a development towards a sustainable biobased economy*" [16], which is "*… a great challenge for sustainability at the planetary scale*" [17].

Despite some scepticism e.g., [18] and a number of errors in research details [19] the big picture and conclusions have not changed [20]: Deterioration of the environment will be a threat to survival of the whole of humankind. We live in a risk society e.g., [21], where one accident can deteriorate the living conditions of a whole continent, and where countless small risks make an ungovernable entity. Human beings' ecological footprint is continuously increasing; it exceeded the natural carrying capacity already in the 1970s and reached an ecological overshoot of 44% in 2006, resulting in an ever-growing sustainability gap [13,22]. The loss of ecosystems also means a reduction in natural buffers for e.g., self-purification abilities [13], and the cost has been estimated to exceed 14 trillion Euros and a 7% loss in global GDP in 2050 [13,23]. To a large extent, it has been accepted that (1) the problems are real, and that (2) the main cause is human activity.

This means that the world will undoubtedly face comprehensive changes in the near future, and these changes will be so large that according to a number of authors a new social contract, involving both science and praxis, will be necessary – as stated by the Science already before the Millennium – "*to move toward a more sustainable biosphere*" [24]. It will also be a challenge for democracy in general [25] and for instance the European integration process [26].

Many approaches and practical tools have already been introduced. These have been supported by a strong general opinion, which has developed into a social norm, forcing enterprises to join the process. However, there is no complete model for preserving the earth, although the idea of sustainable development with its interpretations provides some guidelines e.g., [27]. Still around the year 2000 the praxis consisted of single separate methods resembling pieces mixed up in confusion without a vision of the whole puzzle. Until today, the approaches and tools for measuring and monitoring [28], selection, design, application [29] and assessment [30] of sustainability have clearly attained strategic and practical relevancy.

Traditionally energy production has been one of the core issues concerning the effect humankind has on the environment. This is also why "*climate policy is principally, but not exclusively, energy policy*" [31]. In the "big picture" it is part of the dynamic interaction between society and the environment, as illustrated in Fig. 1 [32]:

- human activities, such as energy production (Society; lower half) have an effect on ecosystems (Environment; upper half), on different scales and in different habitats. The effect can be measured as discharge (arrow from "Society" to "Environment");
- the impacts can be seen in the state of the environment, usage and sustainability of resources, well-being and growth of the population. Examples of these impacts include acidification and climate change;
- the impacts are reflected in society through observations and direct effects (health, state of the environment; arrow from

Table 1
World population (millions) since 1800.
Sources: [9,37–39].

Year	Population
1800	900
1860	1200
1900	1625
1950	2500
1987	5000
1999	6000
2011	7000

“Environment” to “Society”), with harmful effects calling for change;
- societal change geared towards removing the problem is a long and complicated process, where the development of social norms precedes practical responses.

When understood as a temporally developing system, this spiral corresponds to the concept of social self-reflection, introduced by modern sociology [33]. Energy production is part of a system representing a significant share of the interface between the environment and society and it is where the rules of the game are dictated as a societal process.

The main *purposes* of this article are:

- to consider macro level theories for understanding the urge for reforms and the necessary responses to the processes of societal change;
- to consider sustainable energy in a wider context and analyse its recent development as a potential part of this reform.

The scope and *logical framework* of this article is the following:

- The state of the global environment is approaching a point where the whole of humankind is in danger. In Section 2 this article reviews and discusses humankind’s limits of existence and dialectics of the human–nature relationship. The discussion takes a macro theoretical and multidisciplinary perspective.
- This creates practical needs – real actions will be necessary – but above all, it creates a need to develop scientific understanding. Section 3 in this article discusses the need for new kinds of philosophy and cross-scientific theories giving rise to new syntheses. Also, in this article the approach is horizontal, multidisciplinary and integrative.
- Change will be a long societal process, and it will be essential to understand the characteristics and dialectics of the process. In Section 4 this article presents and discusses the three-layer model (3L; presented earlier by the author [5]) of societal chance.
- The production of energy has traditionally been one of the core issues concerning the effect humankind has on the environment, and in the process of change, the potential reform of the energy sector will, therefore, be in a key position.
  This article reviews and discusses (Section 5) the way the already established renewal of the energy sector corresponds to the 3L model, and the diverse potentials of the anticipated further progress.

2. From unlimited growth to sustainable development?

“Finite resources imply that population must eventually stabilise. Our only choice is to control it consciously, humanely and democratically or to wait for real limits to do it for us.”
—Blake Alcott, 2012 [34].

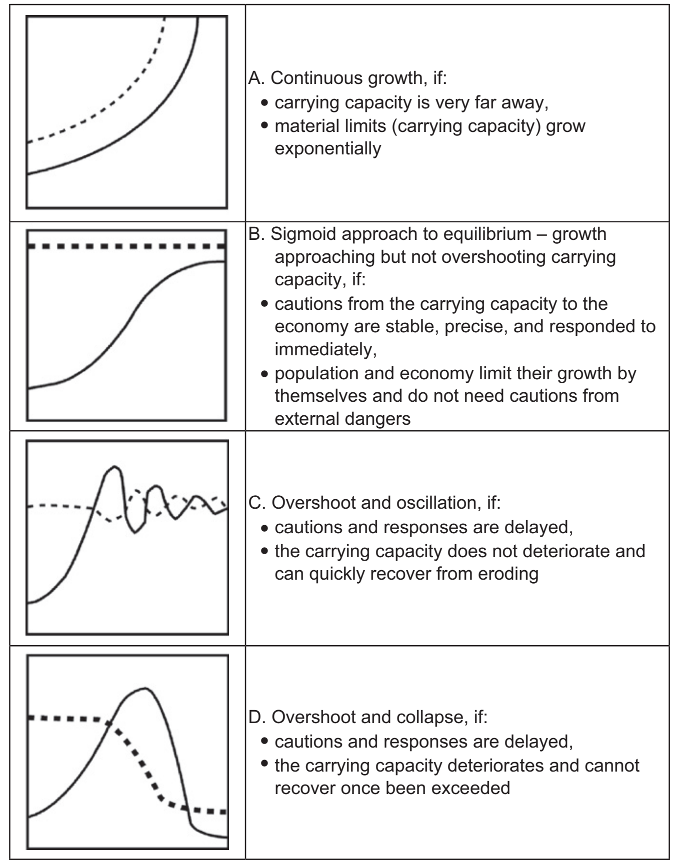

Fig. 2. Schematic alternatives of population development (dotted line=carrying capacity, solid line=population and economy; *source*: [8]).

2.1. Population growth and carrying capacity

The deterioration of the environment has only now begun to be accepted as a real threat to humankind globally. Despite the vast tradition of research, monitoring and observations since the 1960s, it was only when the first alarming signals of climate change appeared that changes happened in the political sphere. Pollution, discharge and population growth are only one part of the problem, being the most visible and easy to understand and measure. Depletion of the sustenance base, poverty and other more subtle economic disturbances are among the impacts that are more difficult to assess and judge as being caused by environmental deterioration alone.

However, it is important to realise that one of the main factors behind it is population growth. For example computational exploration of integrated assessment models reveals an almost one-to-one correspondence between population and productivity growth assumptions, the degree of climate change, and the optimal response to climate change. Continued growth greatly increases the severity of climate change. Fortunately this also means that reductions in the growth rate of the population can be effective in controlling climate change [35].

Population growth has been accelerating in history until the early 1970s (Table 1), but today also a smaller growth percentage means about 90 million new people every year e.g., [36]. Population growth rates

- never exceeded 0.5% per year until 1750
- never exceeded 1% per year until 1930
- never fell below 1.5% in 1950–1995
- reached their all-time peak of 2.1% per year around 1965–1970, being far higher in certain regions (e.g., developing countries in Africa and Asia; [9,36])
- have decreased in 2000s to their present level of below 1.2% per year [37].

A widely used concept in demography is the **doubling time** of population. Its estimate is 69.3 divided by the relative change (percent; rounded to the nearest 0.1 year; exact: ln2/ln(1+growth percent)). According to this an increase of only 1% per year means that the population doubles in ca. 70 years. It sounds like a paradox that if the annual global population growth rate was only 0.0007%, the population would be about 6 trillion in 10000 years. If the populations continued to grow in each major region of the world at the rate observed in 1995, then the population would increase more than 130-fold in 160 years, to about nearly 700 billion in 2150 (examples by [9]).

The human population growth curve has always, but in recent times in particular, been much steeper than exponential or logistic growth curves. In some areas growth has been slow, but in others explosive. The growth has been very fast during the last decades especially in developing countries [9]. Between 1990 and 2010 the world population has increased by 30%, most rapidly in Nigeria (62.4%), and Pakistan (55.2%). In comparison with these figures, however, the 2000s have been encouraging, as the growth rates have declined considerably, the figure now being below 1.2% per year globally [37,39].

It is an axiom of ecological economics that resource depletion and environmental pollution depend on the size of the population, and on the amount of goods and services each member consumes, modified by the technological efficiency of production [34]. The basic demographic formula $I=PAT$ implies that there are certain critical factors that affect the impact (I) that human societies have on the environment. The population (P), its level of affluence (A) and the technology as efficiency (T) are factors that depend on the demographic characteristics of the area, which may change over time. The main point of emphasis, however, is that population size remains a relevant factor when it comes to environmental sustainability, although and as the formula enables, the other factors may include conscious operations towards sustainability (cf. [34]).

The significance of population growth is always intertwined with carrying capacity, not only of each region but also globally. Schematic alternatives of the relationship of population growth or its fluctuations and carrying capacity are illustrated in Fig. 2. It is widely accepted that the carrying capacity of the environment sets the limits for population growth [40]. Its quantification is problematic, however, as the human carrying capacity is "*the estimated maximum number of people who can live … long, healthy, self-fulfilling lives*" [40].The concept is far from being universally consistent, as no exact limits can be set, and decisions related to social carrying capacity are normative and social ones [41].

A number of world models have tried to analyse this relationship e.g., [2,8,9]. Cohen [9] reviewed more than 65 estimates of the global human carrying capacity, the earliest from 1679, and the latest from 1995. The estimates vary from less than one billion to more than 1000 billion. A considerable part of the computations "*… are based only on the capacity of the earth to feed mankind, with no consideration of any other problems and questions after raw materials industrialization and pollution*" [42], being therefore estimates of how many people can live *off* the earth, not *on* the earth.

Most estimates suggest that the maximum supportable human population could go up to 10–15 billion, while the highest estimates would "allow" as many as 10 or even 100 times more. Strikingly the estimates are increasing, despite modern demographics, along with newer models. Still, the most frequent estimates place the limit between 4–8 and 8–16 billion, more than half of the estimates between 4 and 16 billion, half of the estimates below 12 billion and three quarters below 30 billion [9]. On the other hand, as Smail has suggested more recently, *"these limits may already have been reached (or soon will be)"* [46].

According to all models analysed by Ghirlanda et al. [53]) "a population capable of maintaining a large amount of culture, including a powerful technology, runs a high risk of being unsustainable". Estimations require more than a demographic arithmetic: it is hardly conceivable that all humans could have exactly the same living conditions, for example, equal nutrition. The question is about human choices that are yet to be made by this and the future generations. Because the human carrying capacity of the earth is constrained by the facts of nature, for instance, human choices are not entirely free and may have consequences that are not fully predictable [9,44,45,53].

As well as the number of people, also the volume of humankind's activities and technical possibilities of exploiting the resources are expanding. Simultaneously the carrying capacity of the environment is declining [45,40,34]. Today, all global statistics and world models e.g., [8,9,47,48] show an explosive growth of human impacts. They resemble the classical curves of animal populations introduced to desert islands, where they have no competition (D. in Fig. 2). If the curves are allowed to run their course, after the early success, they will show an overrun and a rapid collapse of the population because of the exhaustion of the sustenance base and carrying capacity.

2.2. Malthus and Boserup—The opposing theories

This problematic is analysed in the following section using two influential themes in macro-demographic theory [9]:

1 the **Malthusian** one: the population equilibrates with resources mediated to some level by technology and a conventional standard of living.
Thomas Robert Malthus (1766–1834) was a political economist whose writings, especially the "Essay on Population" (first published in 1798 [49]), have "*…generated more misunderstanding and personal vilification than any comparable figure in the history of social and political thought*." [50]

2 the **Boserupian** one: (1) agrarian population growth is compensated by migration to new areas, and (2) technological change is itself spurred by increases in the population.

Ester Boserup (1910–1999) was a Danish economist and sociologist, whose writings about the interrelationships between economic, demographic, and technical change e.g., [51] have had a major impact over the last quarter century on the evolution of thought in anthropology, demography, economics, and sociology.

Malthus was the first to bring all the ideas of population growth problems together in some kind of coherent theoretical system [9,50]. Human beings' innate biological urge to procreate is stronger than their ability to provide the necessary food for the ever-increasing numbers of their offspring. This is true for any natural biological organisms, which are checked by natural systems, including nutrition and enemies. Human beings have a tendency to multiply their numbers faster than they can increase their food supply, too. The populations will or must be checked somehow from time to time—whether it is by famine, war,

Table 2
Malthus and Boserup in selected literature reviewed (edited by the author).

Source	Contents	Remarks
[54]	General: - material preconditions are primary for the well-being of human societies	Identical to Malthus
[56,55]	Unified growth model: – the economy evolves through a demographic transition resulting in reduced population growth and sustained income growth; – the Malthusian regime vanishes endogenously in the long run, reinforcing the importance (conscious or unconscious) human activities (culture)	Malthusian and Boserupian theories coexist
[43]	Models reviewed: – all models agree that a population capable of maintaining a large amount of culture runs a high risk of being unsustainable; – a variety of steady states are possible, Malthusian checks employed	Supports Malthus
[45]	Model; Lotka-Volterra application: -the course of the environment and population displays oscillations that do not lead to extinction—it still would lead to a significantly decreased quantity of population	Supports Malthus
[44]	Historical: – any factor that causes large resource depletion may lead to a general crises; – material preconditions are primary for the well-being of human societies	Supports Malthus
[57,58]	Historical: – a population may respond to a harsh environment by increasing yield via improved agricultural methods; – a society can only improve welfare by either increasing mortality or decreasing fertility"	Identical to Malthus; Boserupian theory coexists
[59]	Historical: – any technical improvement can only relieve misery for a while, for as long as misery is the only check on population, the improvement will enable population to grow– resulting in more people in misery; – no simple solutions are evident … One must work at being sustainable	Identical to Malthus
[60,61]	Global; pre-historian data (1–1500 CE): – resource surpluses beyond the maintenance of subsistence consumption were channelled primarily into population growth; – societies characterised by higher land productivity and an earlier onset of agriculture had a higher density	Supports Malthus; dispels a non-Malthusian theory
[62]	8 European countries (1960–1998) – an increase in real output per capita: higher fertility – positive employment shocks: deterioration of fertility	Supports Malthus
[63]	Central Africa: – "… reduce the pace of deforestation … caused by an agrarian system … growing population densities" referring directly to the Malthusian dynamics; – propose the Boserupian theory for conscious actions, which "also has its limits and beyond these limits, Malthus will be right again"	Malthusian and Boserupian theories coexist
[64]	Côte d'Ivoire: - innovation has been largely able to compensate for the repercussion of increasing population pressure, which again seems to be unleashed after a critical population density is attained	Malthusian and Boserupian theories coexist
[65]	93 countries, 1975–1996: – population growth: increasing CO_2 emissions worldwide; – the impact more than proportional (increase 1% in population, 1.42% in emissions)	Supports Malthus
[47]	Environmental: -technical evolution a necessary precondition but not sufficient alone, for achieving sustainability	Supports both Malthus and Boserup
[40]	Environmental: – carrying capacity can be redefined upward; – still there are limits, they just can be adjusted	Malthusian and Boserupian theories coexist
[46]	General: – indeed finite limits to global human numbers; – still time to choose whether this dramatic decrease will be under conscious control or essentially chaotic	Identical to Malthus
[66,67]	General: – the expansion of human activities causes decline in biodiversity, ecosystem resilience and buffering capacity, thus narrowing the scope of human adaptations – abrupt and irreversible ecosystem changes may lead to drastic drop in population	Support Malthus
[47,48]	General, cultural evolution: -not the reproduction rate but the collective experience of knowledge, habits and culture determine the population growth rate	Malthusian and Boserupian theories coexist
[34]	General; comprehensive review: -lower population growth can only help to alleviate poverty – regardless of one's estimate of future population size or carrying capacity	Supports Malthus; reviews also opposing views

pestilence, or voluntary "human methods", is up to human beings to choose, according to Malthus.

Malthus' principle of population [49,50] is shortly summarised below (Malthus' moral restraint and other findings, many of which have been subject to a vast variety of debate, writings and critique ever since, are excluded here):

- Three propositions:
  - population cannot increase without the means of subsistence;
  - population invariably increases when the means of subsistence are available;
  - the superior power of population growth cannot be checked without producing misery or vice.
- The power of population growth is indefinitely greater than the power of the earth to produce subsistence:
  - the geometric power of population increase;
  - the arithmetic power of improvements in food production (neither of which were meant to be taken with mathematical precision, but rather as reasonable suppositions).
- The two unequal powers must be equated somehow: the preventive and positive checks are at work keeping the population down to subsistence;
  - preventive checks: means of voluntary restraint on birth rates (abortion, infanticide, prostitution and other 'unnatural' attempts to accommodate the constant passion between sexes);
  - positive checks: higher mortality rates and lower life expectancy (war, pestilence, and famine).
- Malthus proposed and believed in human beings' capacity for reason and foresight to act as a preventive check, meaning a controlled future instead of an ungovernable and chaotic world with active positive checks.

Malthus observed that in the nature plants and animals produce far more offspring than can survive, and that human beings too are capable of overproducing if left unchecked. He concluded that unless family size was regulated, human misery produced by famine would become a global epidemic and eventually consume humanity. Malthus' view that poverty and famine were natural outcomes of population growth and food supply was not popular among social reformers who believed that with proper social structures, all ills of humanity could be eradicated.

Although Malthus thought famine and poverty were natural outcomes, the ultimate reason for those outcomes was divine institution. He believed that such natural outcomes were God's way of preventing human beings from being lazy. Both Darwin and Wallace independently arrived at similar theories of Natural Selection after reading Malthus. Unlike Malthus, however, they framed the principle in purely natural terms both in outcome and in ultimate reason. By doing so, they extended Malthus' logic further than Malthus himself could ever take it. They realised that producing more offspring than can survive establishes a competitive environment among siblings, and that the variation among siblings would produce some individuals with a slightly greater chance of survival. This, in turn, is in complete analogy with the evolution of any species [52].

Malthus' key expressions to underline are 'capacity' and 'when unchecked'. He claimed that the power of multiplication has never fully been exercised or realised. On the contrary, he insisted that"… *in no state that we have yet known, has the power of population been left to exert itself with perfect freedom*". In other words, he realised the power and the mechanism that could be changed by human beings: "… *the sums of the various checks must be sufficient to neutralise the power of increase.* (…) *By promoting* (…) *moral restraint we can reduce the sum of vice and misery which would otherwise be the necessary consequence of the operation of the principle of population*" [49]. In a way, there is an equilibrium, the parts of which are changeable and replaceable. This gives human beings the opportunity to control their own future by replacing vice, famine, war and pestilence with planned human actions.

Ester Boserup presented "The Conditions of Agricultural Growth" in 1965 [53]. It heralded a breakthrough in the theory of agricultural development. Since then, it has also come to represent a more general technological optimistic view of world development, which is in contrast to Malthus' thoughts. Whereas 'development' had previously been seen as the transformation of traditional communities by the introduction or imposition of new technologies, Boserup argued that changes and improvements occur from within agricultural communities, and that improvements are governed not only by outside interference, but also by those communities themselves. She concluded that technical, economic and social changes are unlikely to take place unless the community concerned is exposed to the pressure of population growth.

In sharp contrast to widely accepted earlier ideas, she showed how population growth might be the main stimulus to agrarian change. She identified successive stages of agriculture, characterised by differences in techniques of cultivation and social structure, and showed how they can be explained by differences in population density [53]. As a matter of fact, also Malthus was of the opinion that without the pressure of population upon subsistence, human beings would never have left the savage state, and if the pressure could be permanently abated, humans would sink back into a state of torpor and lose all the advantages of civilisation [50].

2.3. Malthus versus Boserup briefly reviewed and analysed

Due to the importance of the contributions of Malthus and Boserup to demographic theory, their works have been widely cited and referred to in scientific literature. Their ideas are often presented in opposition to each other in relation to topics ranging from population growth and carrying capacity to societal development. Due to the vastness of the area of application and volume of literature related to the Malthus–Boserup dichotomy, an exhausting review is beyond the scope and possibilities of this paper. In the following section, however, a brief review and analysis is given, based on some selected influential references. Some of the main contents have been collected into Table 2.

A dominant view has been that material well-being is of primary importance for human societies, and that social disturbances (including e.g., revolutions, economical chaos, famine, war, emigrations) have commonly emerged in connection with food scarcity caused, for instance, by climate and environmental change, overpopulation, overconsumption and bio-productivity fluctuations [44,54,45,59,65,61]. This is backed up by observations and empirical data regarding population growth and its relation with environmental deterioration and declining carrying capacity and sustenance base [40,34,46,65,62,56,61,66,67,41]. This is in line with the Malthusian view, according to which material preconditions set the limits of existence. These limits have been extended by the discovery of massive fossil reserves, giving human beings the impression that there are no limits at all [1].

Nobel Prize winner Richard Smalley (chemistry, 1996) reinforces this view in his ranking system of human needs (Fig. 3, [54], also [68]). Especially in the context of this paper, energy supply is considered of vital importance, as all other supplying systems depend on a secure operation of the energy supply. For example, poverty means limited or complete denial of access to

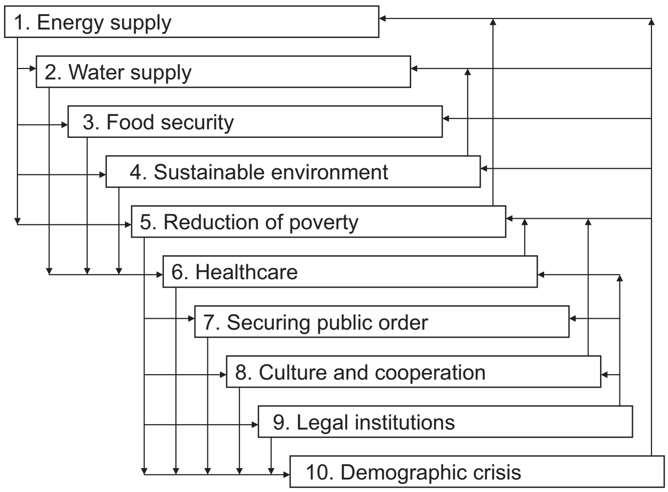

Fig. 3. The complex system of human preferences and global challenges ([68] according to [54]).

different supplies, and fighting against poverty in an isolated manner, in other words separating it from other priorities, would be ineffective in the long term due to unresolved energy, water, food, and environmental problems. Therefore, reforming the energy sector is a highly important challenge to be faced in the immediate future, and analogously it should be treated as a comprehensive societal process.

Another general notion concerns the complex interrelationships between population, its mobility and demographic transition, and environmental and societal change [40]: "*long-term sustainability depends on solving major societal problems*" [59]. This also refers to the possibility for conscious human choices and actions, even cultural evolution: The key might be "*collective experience* (…) *and culture*" [48] and development of information, which "… *obeys its own evolutionary laws* (…) *in successive stages*" [47]. The aspiration for technical reforms and more comprehensive societal development towards sustainability can easily be interpreted being in support to both Boserup and Malthus.

Alcot [34] reviews some views in opposition to those of Malthus, many of which, he reveals, are based on false interpretations or political motives (e.g., "no state-imposed population control", "no population lobby", "food availability and environmental scarcity no problems", "the population bomb defused"). Neumayer [69], on the other hand, did not find empirical support for the neo-Malthusian view that fertility is kept in check by scarcities. The explaining factor may be the extent to which Malthus has been interpreted literally, e.g., "scarcity limits fertility" is not the same as to say "scarcity limits population". Malthus' postulation was that scarcity increases mortality via famine, war and pestilence, which would make Neumayer's reasoning logical.

Analysed as single separate theories, the main conflict between Malthus and Boserup relates to scale, which can be described with the help of the dilemma of 'vertical' and 'horizontal' carrying capacity:

- the vertical carrying capacity, at a local or regional level, has been improved by means of e.g., the green revolution;
- the horizontal carrying capacity, at a larger scale, ultimately globally, has been utilised to substitute deficiencies on a smaller scale.

The limit of the environment's carrying capacity has not, until now, been reached on a global level, and natural resources have therefore seemed inexhaustible. There has always been a possibility to develop according to Boserup's meaning. If one area or region has been exploited or emptied from resources and a sustenance base, there have always been other areas available. The "waterloo" of Boserup's model is the situation where migration to new areas is impossible, and all replacing resources have already been utilised. In fact, Boserup's theory is a model of no limits and it is valid only for single separate regions surrounded by unlimited resources and the possibility of migration and substitutions.

The global carrying capacity cannot be exceeded. When no further use of natural resources is possible, and when technical reforms will no longer be sufficient, and when substitutions through migrations or import are impossible, the limits will be met at a global scale. Here, the Malthusian thesis proves valid. Another question is when, at which point in time, will these material and technical limits be met? All speculative models indicate that it might take a couple of generations, but in any case it will be an extremely short time on a geological scale.

Despite the apparent differences, a number of authors, also cited in Table 2, have pointed out that rather than representing contrasting views, Malthus' thesis and Boserup's theory in fact complement each other. This has led to a new formulation of the Malthus–Boserup dichotomy: On the whole they explain the same thing, only on a different scale and from different points of view. The Malthusian perspective is a holistic one, in which all conscious endogenous self-reflections carried out by humans can be interpreted as "preventive checks". On the other hand, while the technical improvements suggested by Boserup are necessary preconditions for achieving a sustainable civilisation, in the long term and within a global perspective they are by no means sufficient alone.

All positive changes boosting sustainability are not "conscious", as they may also be the result of the population's structural internal constraints, as, for example, the demographic transition towards both lower mortality and fertility [62]. Therefore, it is essential in the future to be aware of all the relevant aspects of the population dynamics. Or as Dolgonosov and Naidenov [47] wisely point out, the "demographic imperative" must be completed by an "informational imperative", as knowledge and cultural evolution "… *is actually the only driving force to the development of civilization*" [47].

2.4. Robbery—The human pattern?

Theoretically and in order to escape from this trap it is not enough only to observe and analyse the end result of the process, but it is crucial to be aware of the pattern behind the behaviour. Environmental sociologists introduced the concept of *robbery* (started by Friedrich 1904, summarised by Massa [51,55]) to describe human activity in relation to natural resources throughout history. As defined by Massa [51], the economy of robbery is based on the overexploitation and carelessness of resources and the environment as well as not taking care of offspring or securing future availability of resources.

In environmental sociology the roots of robbery have been explored, in addition to texts by Malthus and Boserup, within the following theories, to mention a few [51]:

- the staples thesis (originally by Harold Innis, ref. [51]).
  The economic development and industrialisation of the peripheries (Canada in Innis' writings) within the World economy has been based on exporting natural resources from the peripheries. These areas are connected to the world economy through staples products and centres–in other words peripheries act as resource pools for the wider economies. The search

for and exploitation of these staples led to the creation of institutions that defined the political culture of the nation and its regions. Innis argues that different staples led to the emergence of regional economies (and societies) within Canada.

- Ecological colonialism e.g., [51,71].
  Resources have been exploited and resource pools have been emptied one after the other without any concern for the end results in those areas. It has always been possible for the exploiters to move to other pools. According to history this kind of ecological colonialism has been the established pattern in peripheral regions. It has been especially successful where political pressure and control has been the least.
- Societal incapability of ecological communication (originally by Niklas Luhmann, ref. [51]).
  The modern and differentiated society is seen as a fighting arena where the different sectors within societal sub-systems are struggling against each other without means of communication. The aim for a common good does not belong to any of the sub-sectors' codes. Lack of communication has resulted in a situation where everyone is trying to fulfil his or her own needs (as also stated in the iterated prisoner's dilemma, e.g., [72]).

The above analysis has explored the definition and criteria for robbery by looking at the end result: Human activity becomes robbery only when the exploitation of the environment exceeds a certain limit of quality and quantity, characteristic of robbery. This could be expressed simply as the intensity of the use of resources, as also the $I=PAT$ formula implies [34]. From this point of view, there are three main factors to be controlled:

- population and the level of its activity;
- technical capability and means of production;
- carrying capacity of the environment.

This means that whether the intensity of resource utilisation achieves the level of robbery depends on these "parameters", and for any given society only these prerequisites would define whether it is capable of robbery or not. It is logical to think that in terms of the above three parameters all societies would always act according to the robbery thesis whenever it was possible, leading inevitably to the conclusion that there must be a **pattern** which always produces the **end result** when it is possible. According to this thesis, the ideal of a life in harmony with nature is only an illusion as the possibilities for fulfilling the "internal insight for progress" are temporally and spatially insufficient.

There is a constant conflict between the common and individual needs, and without communication it is the personal needs, which take over. The same situation is also central in the evolutionary approach: It is clear that survival, improvement of fitness and maximisation of well-being have been the main strategies even in the early evolution of human beings. This has resulted in a pattern, according to which individuals – and without communication of individuals also communities – have striven for the maximal utilisation of their environment. It has most probably been one of the main advantages in human and social evolution. It sounds only logical that this has formed the mental sphere of humankind and the social norms of communities throughout history.

Nature and its resources have always been the source of livelihood for people, and this has also shaped human beings' relationship with their environment. It is understandable that this "bottom stream" in both individuals' and communities' collective mind has resulted in an established pattern at a societal level and within the whole of humankind. This suggests that the deeper essence of robbery ultimately lies in the evolutionary heritage of human beings. Throughout history technical devices for the (maximal) exploitation of resources have been developed. This pattern, driven by the "internal evolutionary pressure", has continued in spite of high living standards and other achievements – resulting in the overexploitation of resources and environmental damage. "…*during the course of human evolution, natural selection has given rise to certain core elements defining human psyche*" [73].

From this point of view, the main challenge of humankind is to free itself from this pressure, make new conscious choices, create new evolutionary and stable strategies as well as societal rules, and launch a new praxis that makes the world sustainable.

2.5. Conclusions

History is full of examples of how formerly productive places and regions have been exhausted, permanently deteriorated and then abandoned, and the population has moved to reside in other places [74]. This has been possible as long as there have still been unoccupied places. But today the "hand of humankind" touches every part of the globe, and raw-material reserves and the sustenance base have proved limited.

The discovery of large oil reserves at the end of the 1900s had a significant effect on discussions and theoretical views. As Hall and Day [1] expressed, "… *it seemed that technical innovations and resource substitutions, driven by market incentives, have and would continue to solve the long-term issues*", and the limits were "… *seen as invalid*". It was also agreed that "*Malthus's premise has not held between 1800 and the present*". But Hall and Day also concluded that "… *our exponential escalation in energy use* (…) *is the principal reason that we have generated a food supply that grows exponentially as the human population*" and that "… *since Malthus's time we have avoided wholesale famine for most of the Earth's people because of fossil fuel use*"[1].

It was mainly the new oil reserves that created the illusion of limitlessness and technology optimism. The expansion of the world economies has nearly always increased parallel to an increase in the use of fossil energy, and when that energy has been withdrawn, the economies have shrunk accordingly. "*Malthus could not have foreseen* (…) *through petroleum*" [1]. Although many have considered the limits-to-growth model as a failure, Hall and Day "… *are not aware of any model made by economists that is as accurate over such a long time span*"[[1].

These conclusions leave us with the fact that growth without limits is impossible in a finite world. *"What is certain is that there are limits* (…)*. This general statement is in complete accord with Malthus' view"* [9].

There is neither a general agreement upon what the factors are that set the limits, nor is there a common shared opinion of the interactions between the factors. Especially the world models created by the Club of Rome have brought the idea of limits into the discussion and incorporated it into general knowledge: according to a very simple demography, it is clear that whatever the limits are, they will be reached quite shortly, maybe even in a couple of centuries [9,42].

The future of the Earth and of humankind is in the hands of human beings. All the choices **can** be made, on the one hand, and **must** be made, on the other, by humankind itself. This is also what Thomas Robert Malthus originally suggested, already over 200 years ago. Hence, there is a fundamental test of humanity for people: Which kind of praxis are people ready to accept to limit population growth and environmental deterioration, to avoid overshoot and collapse, and to consciously choose among alternatives other than D in Fig. 2.

3. Towards a multidisciplinary scientific understanding?

"In these days of specialization there are too few people who have such a deep understanding"–Feynman [75]

The urged change will in any case be a multi-task and a multi-branch exercise and an orientation for the future. This means that no single branch of science can understand, outline or solve the whole problem alone. For instance the reforms the energy sector must carry out are commonly seen to be primarily technical, and while technology is necessary for new energy solutions, the whole field must also be understood and managed economically.

Moreover, change is not possible without social acceptance in a wider perspective, at the level of general opinion. For example, in order to introduce a new single separate power generation unit, its acceptance by the local population is necessary. On top of this, change should involve industries and a number of stakeholders along the whole value chains of the new energy solutions. Among the prerequisites for the new solutions are new regulations, laws and other general rules of the game, or conversely, old solutions must be interpreted in a new way.

Still, this is not enough. Comprehensive reforms must be anchored in the political sphere as well. They must be integrated into the national and regional strategies, through which they are put into practice and managed. They have an impact on regional economies, employment, rural vitality, and environmental matters, to name some of the most important spheres. But the main point the list reveals is that reform consists of a comprehensive process of change, where a cross sector and multi-scientific know how, expertise, comprehension and other capabilities are necessary. Hence, multidisciplinarity is of particular importance in the energy sector [70–72,76,77].

The last 100 years of history have demonstrated the difficulty of this kind of philosophical orientation. So far, no disciplines or science as a whole has been able to produce neither a structured analysis nor a satisfactory picture of the "human–nature (resources)" relationship. We have a history of winners and (over)exploitation which, until recently, has been seen as a great achievement, as resources have been considered unlimited cf. [51,74,78–81].

This can be understood in the light of the history of science: In general science has been geared towards detailed knowledge, and from philosophy towards specialised disciplines and new branches of science. The amount of detailed information in science has expanded explosively. This has created strong barriers, which isolate the generally accepted "real" science from the "discriminated grey zones" between disciplines. The integrative approach has met with the academic dilemma of the grey peripheries between vertically isolated disciplines e.g., [82].

Environmental science, for instance, has traditionally been governed by natural sciences e.g., [51,81], which is insufficient for today's needs. Environmental sociology e.g., [51,82–88] prepared the ground for the *second environmental science*, introduced in the early 1990s by sociologists [51,78]. It has been anticipated that this horizontal approach will show the way to the next paradigm shift or revolution in science [51,89]; cf. [90]. Later there have been signs of a more general acceptance of this approach. Instead of merely adding sociology to natural sciences, all branches of science should be included in this horizontal, multidisciplinary and integrative program also [94].

Today, the progress of environmentalism culminates in practical measures of enterprises. Development is rapid, and environmental protection has become a part of the competitive advantage of enterprises. However, there are several severe problems. Changes of legislation, the pressure for change in the near future as well as the strengthening of various other motives in environmental protection have given rise to great turmoil in environmental strategies and methods. Especially SMEs are having difficulties as, for example, investments in environmental management are large in proportion to their size, and they can only utilise tools developed by others, which they can use but which will not demand too much capacity. Also, a commitment to environmental protection is a risk since there are no generally accepted methods.

But the most serious defect is that there is a lack of structure in the field and its theoretical basis is defective—lack of cohesion is typical for the development of this rapidly expanding field, which has been based on several different and separate methods.

There is clearly a need for a new synthesis and philosophy, which is able to integrate the expertise of traditional natural sciences with, for instance, technology and process control, legislation, economy, strategies and management, organisation development, and social operations [95]. It is clear that the combination of research, education and practical work will be necessary in the near future. The necessity of this new philosophy arises from two main justifications:

- practical needs for preserving the sustenance base of society
- scientific needs for understanding the information produced by isolated specialised disciplines within science.

In comparison with the traditional vertically highly detailed and specialised branches of science, this cross scientific approach combines several branches and theories into a horizontal multidisciplinary and integrative program.

Today, environmental aspects are about to be integrated into sociological theories of industrial and reflexive modernisation. "Ecological modernisation seems to be the general concept that describes this growing consensus", it is "… an ecosocial restructuring of the technosphere, (…) an ecological switch of the industrialization process into a direction that takes into account maintaining the sustenance base, (…) overcoming the environmental crisis without leaving the path of modernisation" [96]. Also production philosophies and practices are integrating environmental aspects. "Whatever name we use, this new paradigm treats human and natural systems in an integrative manner" [76].

This development will be a long process, and it will employ both the academic community and practical actors. Because of the academic tradition there is no generally accepted theoretical framework for the approach. Although scientific development is a slow process, practical solutions are needed all the time.

4. Understanding the change

"Every reform was once a private opinion"—Ralph Waldo Emerson 1841.

All eras in history have had norms, structures and practices of their own. They are collective manifestations of society, while at the same time they consist of activities and values of often countless individuals and organisations. There are no individual people who dictate the rules, and societies have tended to move towards a kind of collective thinking and self-organisation. It seems impossible to change the current system, especially through individuals. But still, history has shown that often all habits have been renewed one after the other. The key point here is the emergence of change and its mechanisms, or in terms of dialectics: How does one detail gradually become prevailing in the whole?

The fundamental thesis with regards to the dynamics of societal change is the *dialectics between details or parts and the whole,* as between the individual and society, or the idea and the

norm. Although certain actions or operations are always processed by single and separate actors, they must still be understood as parts of a wider context. No individual or enterprise is able to live outside of societal constructions. Enterprises are open systems [97,98] in a world of constant societal change and pressure. Therefore, their behaviour, while simultaneously capable of being innovative, also follows some general rules and patterns, and their degree of independence and freedom is relative. This constellation is fundamental from the enterprises' point of view when they make conscious strategic and operational choices. It is also fundamental for the evolutionary development of enterprises and organisations as a whole and as parts of society.

The Three Layer (3L) macro level model for understanding societal change has been presented earlier by the author [5], and it is briefly summarised in the following. The 3 L-theory suggests that:

- norms, the social base and mental development are primary factors in the beginning and in terms of the dynamics of change. They are the mental environment that the new emerging ideas will face.
- Change always comes from a variety of ideas, generated by individuals and inspired either by innovations or nuisances, defects or other inconveniences of the prevailing system.
- Deviating or nonconformist ideas always emerge in the social context under actual prevailing norms, structures and practices, and the great majority of ideas never overcome the old ones.
- The continuous conflict between new and prevailing thoughts is solved in the *social selection* process, which determines the extent to which new ideas become generally accepted.
- Some ideas are accepted by other people and groups, and they gradually become approved of, accumulating in the whole society and encouraging new ones. These finally force the old paradigm to give way to the new one.
- The new winning thoughts are reflected in a change of rules and of other supporting structures, such as legislation, institutions, market behaviour, and operational patterns in enterprises and other organisations.
- All general operational patterns and practices have developed through a long process, which ensures that they are socially accepted and follow the existing norms.

Summarising, the change consists of three successive and interactive layers (Fig. 4), which have their own evolution and dynamics:

1 **Social base**
The social base develops in a mechanism where single separate ideas, subject to social selection, become more generally accepted, then form the general consciousness and opinions, and finally social norms, which control society as unwritten laws. For a *certain* given thought change might never take place, and it may vanish or be left within a marginal minority. Actually the main part of new thoughts is excluded due to societal pressure. But *some* thoughts generated in society, giving rise to anomalies against the prevailing norm, are eventually accepted, encourage new supporting observations and ideas, and cause an accumulation of anomalies. Gradually, the *single* deviating observations and thoughts overcome the old norm, and finally a new *societal* pattern is established. The main phases are [5]:
   – single observations of defects, deviating and nonconformist ideas and anomalies against the prevailing norm emerge.
   – The new ideas become more common.
   – The first phase of societal activity: formation of groups, coalitions and movements ready to fight for the idea emerge.
   – Formation and strengthening of general opinion occur.
   – Confirmation of the social norm: an unwritten law, which controls the behaviour of the majority of the society.

2 **Supporting structures**
The supporting structures prepare motives for bringing the idea into practice. Legislation and other regulations cause an obligatory normative motive. Changed customer behaviour gives rise to market based motives, and pressure from the environment produces the societal motive. Efficiency and quality thinking prepare the ground for operational voluntary motives and a complete philosophy may develop into an ethical motive. The norm or mental base of society is impaired without a corresponding practice—general rules and other supporting structures are necessary in order to prepare the ground for putting the norm into practice. The development of supporting structures is classified according to their motives [5]:
   – ethical and political motive: a total philosophy, world view or a way of thinking is established in society, which is often institutionalised through political interest groups and policies.
   – Normative motive: legislation and other regulations establish new general rules, administration is readjusted to new conditions, and follow-up and research are reoriented.
   – Market based motive: customer behaviour changes, demands from clients become stronger.
   – Societal motive (individuals): because of the new social pressure and behaviour of other people, the new way of thinking becomes more attractive.
   – Operational motive: internal efficiency, quality, productivity and competitive strength in terms of the new way of thinking takes over in the enterprises; adjustment of one's own activities to the new way of thinking

3 **Practical responses**
The practical responses start from avoidance and separate technical improvements and develop into strategies and integrative practices. Operational patterns are the final implication of the development of the social change. Because of the need for general rules and other supporting structures there is a time lag between the mental base and practical responses. The first reactions to new ideas are usually denial or understatement of the phenomenon or its impacts, and avoidance of disadvantages as they become obvious. After the establishment of the first laws a new practice is no longer voluntary. Social order and motivation for progress are encouraged through other supporting structures. Phases of this process are classified as follows [5]:
   – rejection and alleviation: denial of the problems, avoidance, dilution.
   – Single separate technologies and improvements for the management of the symptoms.
   – Strategy, integration and synergy: search for efficiency and competitive strength.
   – Societal patterns: adaptive changes at the societal level, and structural changes.

The 3L is fundamentally and strongly an evolutionary model and it has been inspired by the following theories and approaches:

Paradigm shift and conceptual evolution
The paradigm shift is based on the theory of scientific revolutions and structural changes, as first crystallised by Thomas Kuhn [90]. This theory has been further explored and improved by David Hull [91,92] who introduced the idea of conceptual evolution (see also [93]). This is completely analogous with the dynamics of the Social base in the 3L

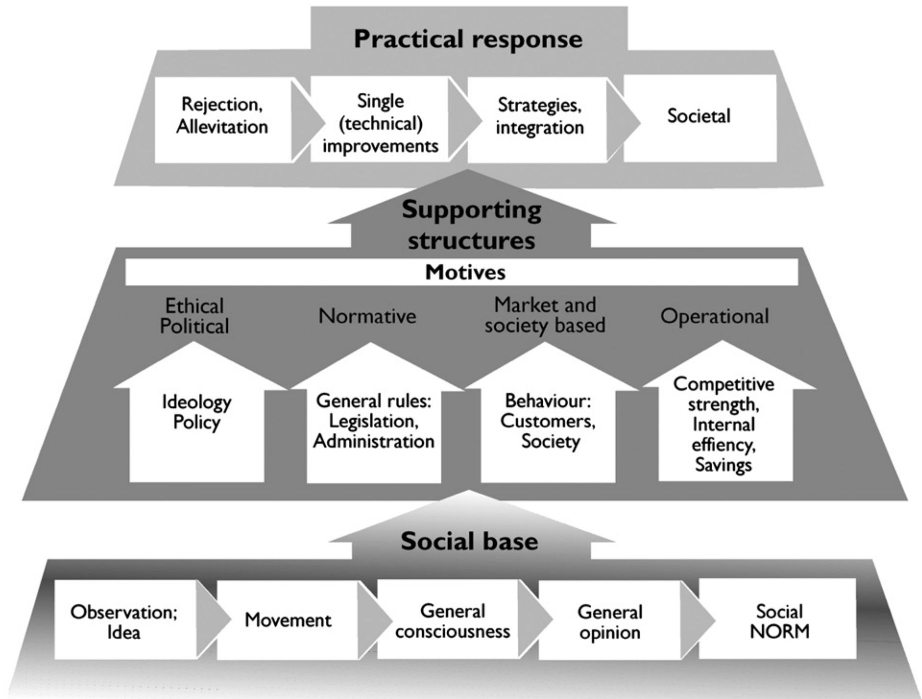

Fig. 4. The structure of social chance: The Three Layer model (3L; [5]).

model, where the underlying thought is that as well as scientific paradigms also other intellectual constructions are subject to the same process of conceptual evolution.

Iterated prisoner's dilemma

The prisoner's dilemma is an example of the game theory, which is a mathematical method for analysing calculated circumstances, where a person's success is based upon the choices of others. It shows why two individuals might not cooperate, even if it appears that it is in their best interest to do so. It becomes "iterated" when the situation is repeated and solutions become strategic choices related to how the other person acts. "*What is best for each person individually leads to mutual defection, whereas everyone would have been better off with mutual cooperation*" [72]. In terms of what is best for society it is essential to break out of the dilemma. In 3L the general rules and hence the supporting structures for bringing the ideas and norms into practical realisation are of high importance. They are motives on the one hand, and incentives and sanctions on the other. Their purpose is to ensure that all actors have the same prerequisites for the aspired actions, according to the new norms and ideas, which have newly been adopted by the Social base of the society. They also reveal the reason for the social lag e.g., [51]: it is possible to put an idea into practice at the general societal level only after it has gone through the selection process.

Ecological modernization

Ecological modernisation means, as defined by environmental sociologists, structural changes in production and consumption, social and cultural maturing and the emergence of new patterns at the societal level, on top of and prior to merely technical reforms. In practice it means leverage to a collective level above separate actors e.g., [3,51]. Ecological modernisation has been the basis for structuring the Practical response of 3L. Even technical evolution can be structured according to these categories from a strategic point of view.

Self reflection of society

The self reflection of the society is the feedback system of how societies and ultimately the whole of humankind can collectively correct its actions and praxis whenever it reflects nuisances and harmful impacts [33]. This corresponds with the interaction of society and the environment as illustrated in Fig. 1 and the actions inside society according to the 3L model.

Diffusion of innovations

The diffusion of innovations is the theoretical model for explaining how novel technical solutions spread across societies, as summarised by Rogers [99]. Although it mainly explains technical innovations, it is clear that the preceding phases, suggested by 3L, are necessary for a successful diffusion.

Cultural evolution

Cultural evolution is the main point of emphasis of the whole 3L model, which hopefully adds value to the discussion about cultural evolution. There is a wide variety of literature about cultural evolution with different opinions concerning the details. The debate explores, for instance, whether the diffusion of thought takes place through replication of the so-called memes (as proposed by e.g., Dawkins, Blackmore and a number of other authors [100–103]) or through a more complicated process of cognition and comprehension e.g., [104–107]. Memetics became a widely exercised program and even the Journal of Memetics was established. But opposing opinions are also strongly supported and promoted, often by evolutionary psychologists e.g., [108]. Some of the discussion has been summarised in [73,104,108,109], while [93] provides a comprehensive review, unfortunately only in Finnish. 3L as such does not take sides with either of these views, the unifying feature remaining that they are all evolutionary.

5. Towards sustainable energy

"*Renewable energy is one of the most efficient ways to achieve sustainable development*" [110], and "*One of the main tasks in this century (…) will be to manage a transition process towards a sustainable energy system*" [111]. Sustainable Energy (SE) has

become one of the key concepts in reforming the energy sector in the EU and worldwide. Among key questions are the following:

– is SE possible, in terms of energy parameters and technology, environmental impacts, social acceptance and economics?
– Is SE enough (for preserving the earth)?
– What will be the process towards SE?

5.1. Sustainable energy reviewed, defined and analysed

Sustainable Energy is a direct descendant of the idea of sustainable development, with regards to its different interpretations and emphases e.g., [112–115], as well as its origins and evolution, in how they are linked with energy systems [116]. There are more than three hundred definitions of sustainable development within the domain of environmental management, but in many of them the original starting point of protecting the environment and taking other aspects into account has been replaced by other kinds of priorities [115]. From the point of view of this paper the original priority of preserving the earth is highly important.

There is a plethora of definitions of SE in recent scientific literature and other sources; some typical ones have been collected into Table 3. Many authors simply refer to the original definition by the Brundtland Commission or give some corresponding phrases on a general level. There are also definitions, which take into account the efficient use of non-renewable resources with the aim to create energy security for "as long as possible". Some offer no explicit definition in one sentence, but instead they list relevant aspects, while others find no single definition at all and are characterized by the lack of a common framework. However, there is an almost overall agreement that all forms of renewable energy belong to the concept of SE. Another cross cutting feature of SE, either explicitly or implicitly, is energy efficiency.

Taking the literature review into account the fundamental contents of the Sustainable Energy Concept are defined in this article as follows. Further, the concept has been visualised in Fig. 5.

1 **Rational Use of Energy (RUE)**—energy efficiency and saving
2 **Renewable Energy Sources (RES)**—materials and other sources (biomass, wood, hydro, solar, geo, wind etc.)

Table 3
Some definitions of sustainable energy reviewed (edited by the author).

Source	Main contents of the definition
[117]	– RES key component of sustainable development – supply in the long term available at reasonable cost, without negative societal impacts – increased energy efficiency
[118] [119]	–support human development over the long term in all its social, economic and environmental dimensions – satisfying essential human needs for both this and future generations – sparing non-renewable energy sources, and replacing non-renewable energy sources with renewable sources – ecological impacts within the carrying capacity of natural systems
[120]	– -does not exceed the environment's capacity to absorb the effects – does not unnecessarily consume resources in ways that ensure rapid depletion
[121] [122]	–the harnessing of energy resources for human use in a manner that supports lasting development (Encyclopedia of Energy) – reduce environmental impacts, are socially acceptable and economically competitive – renewable energy, distributed energy systems, natural gas, demand-side energy efficiency
[123] [124,125,126] [127] [128] [129]	–a living harmony between the equitable availability of energy services to all people and the preservation of the earth for future generations –"20–20–20" rule; 20% RES, 20% improved energy efficiency, 20% decreased green house gas emissions by 2020 –no single definition (…) a wide range of interpretations (…) lack of a common framework –energy savings on the demand side, efficiency improvements in energy production, and replacement of fossil fuels by RES – climate crisis solutions – the two pillar definition (RES and RUE alone) falsified
[130] [131]	–efficient use of both diversified replenishable and nonreplenishable energy resources while severely limiting the ecological footprint – balance of energy production and consumption – no, minimal, or negative impact on the environment but gives the opportunity for a country to employ its social and economic activities
[132] [133]	–maintaining the capability to provide non-declining energy services in time – meets the needs of the present without compromising the ability of future generations to meet their needs – all renewable energy sources and usually (…) energy efficiency
[134]	– meets the needs of the present without compromising the ability of future generations to meet theirs – replenishable within a human lifetime and causes no long-term damage to the environment – all renewable energy; fossil fuels are not
[135]	– can be produced without using resources that are not able to be renewed – renewable energy
[136] [137]	–minimal negative impacts on human health and the healthy functioning of vital ecological systems – energy generation, efficiency & conservation, energy independence – enable to become a significant portion of energy generation long term, can reach and get below power parity by 2020 or earlier, compared to traditional fossil fuels – low to zero or even a negative carbon footprint, no significant side effects to earth's resources – boosts long term economy and job opportunities

3 Integration of RUE and RES

4 Sustainability management

There are a number of technologies for both **RUE** and utilising **RES**, which can all be implemented alone as separate solutions or designed to be used as a combination. However, the **integration** of RUE and RES technologies (some examples of which are indicated in Fig. 4) will be the key to the creation of complete solutions. With different combinations of the available RUE and RES technologies and regional RES energy it is possible to outline alternative solutions with different degrees of energy self-sufficiency. This concept can be applied to any target, whether it is a region or a separate building, and anything between these two extremes. It is then up to the decision making system to choose the alternative which has the best possible outcome from a number of perspectives.

Fig. 5 illustrates how the SE concept can be composed in practice. The starting point is implementing RUE technologies. Then, the energy which cannot be saved or upgraded and is needed is produced by RES. RES, in turn, can consist of a number of raw materials or other sources, which are formed or can be collected from the same region where it is used. These sources can be utilised using several technical solutions. The use of RES from the local region refers strongly to the distributed energy strategy. In principle it is possible that also large centralised energy production units adopt RES for their raw material production. This, however, is a question of technical and economical optimisation.

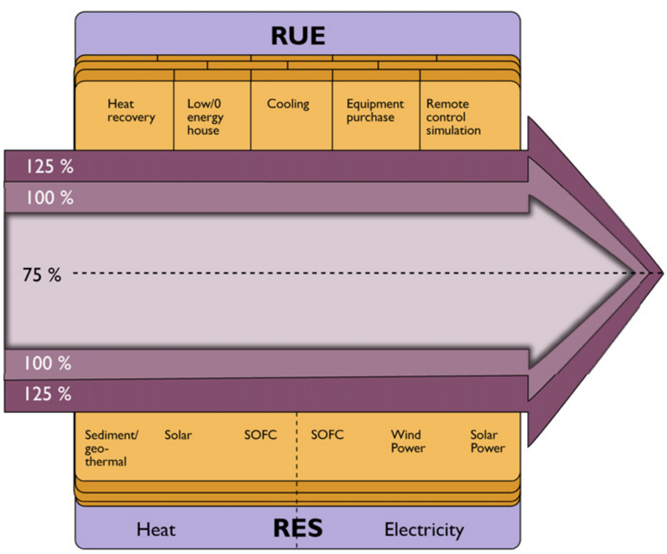

Fig. 5. Integration of RUE (rational use of energy) and RES (renewable energy sources).

It is also essential to establish management systems for implementing sustainable energy strategies and separate projects. There is always a danger that these projects become a new field of ecological colonialism where the old pattern of robbery (cf. Section 2) will take over. A number of examples have already been reported e.g., [129,138], where maximal economic gain and carelessness of the environment have been applied for producing renewable energy in the name of sustainability. A potential concept for operationalizing and monitoring sustainability management by combining performance (impacts) and organisation (actions) is presented in Fig. 6 (modified after [139]).

This formation of SE is in full agreement with the early definition by Dincer [117], according to which RES have much less environmental impacts (presupposing proper sustainability management) and cannot be depleted, unlike fossil fuels that indeed are finite. The analysis above also supports Dincer's conclusion that the use of RES favours power system decentralisation and locally applicable solutions.

As well as providing a definition it is essential to analyse whether SE is possible or realistic in practice. This can be assessed by looking at the relationship of SE and the global use of primary energy. The first unavoidable question relates to the total amount of energy consumption, and the second to the amount and the way in which RES are used.

World primary energy use in 2009 was 12150 Mtoe (ca. 140 PW h) of which 13.5% was RES; correspondingly the consumption was 8353 Mtoe (ca. 100 PW h) and the share of RES was 16.2% [140]. According to a recent review [138] the main global scenarios regarding the use of energy all suggest that there will be sufficient availability of fossil fuels in the future. For instance, the newest scenario by the International Energy Agency suggests that the global primary energy demand will increase by 35% from 2010 to 2035, with China and India accounting for 50% of the growth. RES will grow the most, but also the use of fossil fuels will increase [141].

However, Moriarty and Honnery [138] conclude very convincingly that the "*… future energy consumption will be significantly lower than the present level*" and "*only large reductions in global primary energy use (…) can meet the (…) problems that future*

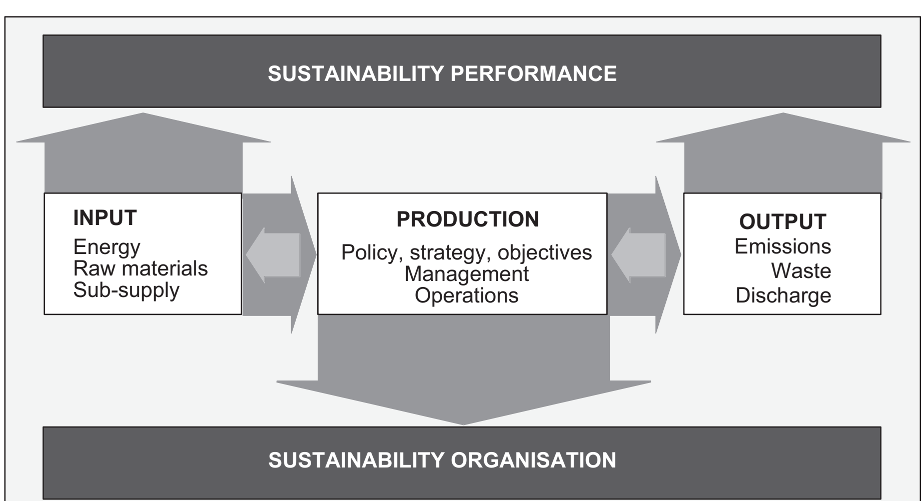

Fig. 6. Production flow chart re-structured into sustainability organisation and performance.

energy use will face" [138]. Recent statistics estimate that both conventional and non-conventional oil reserves will meet the projected world demand only for some 50 years and gas reserves correspondingly for 80 years [142]. These figures are in full agreement with the theoretical analysis presented in this article. It also underlines the importance of future energy efficiency and saving.

There are also suspicions that the "*Future use of RE is (…) highly uncertain, for a variety of reasons*" [138]. The main arguments relate to the economics and realism in the potential diffusion of RES technologies, and the sensitivity of RES to adverse environmental impacts (also [129]). According to the economic arguments [129,138] it seems impossible to deploy enough RE globally to move towards sustainable energy on a large scale. The analysis is to be taken seriously, though as such it is not valid for the future economics of RE technologies for the following reasons:

The analysis only looks at the costs of today's technologies—which are in an early developmental phase, with no mass production, poorly developed value chains, and with the whole prevailing structure including opposing businesses and regulations against them e.g., [32]. Further, it does not differentiate between the structural options of energy generation, namely centralised and distributed systems, which might have a significant impact on the economies of energy solutions. According to a recent analysis even just normal investments in RES technologies have performed exceptionally well [143], the main risks being changing policies, regulations and other general rules.

Also the benefits beyond the normal business profitability can be significant. "*Each € not spent on imported fossil fuels, and instead spent on a regional bioenergy project can have a multiple effect*" [144]. This **regional added value** is the sum of all values being produced in RES projects, including monetary aspects, reduction of costs, increase of purchasing power, new created employment, higher tax income, and social, ecological and ethical aspects. For instance, in Rhineland-Palatinate (Germany) the saving potential created by compensating fossil fuels with available short-term renewable potentials is ca. 400M€ [144]. One of the repeatedly up-coming and generally accepted points is that RES generate more jobs than conventional energy. For instance per installed megawatt RES gives 1.7–14.7 times more jobs than natural gas, and four times more than coal [145].

Adverse environmental impacts include, for instance, a potential depletion of ecological carrying capacity and a diminishing RES potential, large land requirements, increased species extinction, large scale pollution [129,138], and that "*widely deployed, RE can act to undermine ecosystem services*" [138]. They are all realistic threats but not as such caused by default. It is always a question of how things will be put into practice—and it is for this end that the concept of sustainability management has been included in the definition of SE.

Empirical material from Finland and reviewed international observations [32,146] show a surprisingly high potential of the exclusive use bioenergy even when materials that are not used for other purposes are included (for classifications of RES potential: [32,147]). Considering the whole potential of all RES, for instance wind and solar power and a more efficient use of bioenergy, the main observations suggest that today's energy demand could be satisfied by RES. Up to 100% renewable energy systems with substantial climate mitigation potential have already been studied and planned e.g., [128,148–152]. However, it is clear that the use of these resources also depends on the carrying capacity and cannot be increased limitlessly.

In conclusion, indeed there is a social demand for a more wide spread use of SE, both in terms of efficiency and energy saving, as well as for the use of especially locally or regionally produced RES. With reference to the analysis of Boserupian ideas, presented earlier in this article, technology can develop in order to take advantage of the existing potential of RES, and replace the use of fossil fuels within the limits of the carrying capacity, without undermining the ecosystem services. By contrast, in Malthusian terms, the use of energy cannot increase without depleting the sustenance base of the whole of humankind.

5.2. *Diffusion of sustainable energy*

The diffusion of SE towards RES based energy self-sufficiency and distributed strategy will be a long evolutionary process at the local, regional and national as well as at the international levels. In rural regions it will stimulate employment, welfare and the regional economy. It offers rural regions a totally new societal role: besides food production, the countryside can also be a source of energy. This process of change will necessarily involve most people, and there will be a huge number of decision-makers involved, from single citizens, families, farmers and enterprises, to the public sector. The process also involves those who need energy, those who produce it, those who manufacture the technical solutions, those who deliver the raw materials, and those who create the general preconditions for the whole movement of decentralised energy production [32,155].

In most places the establishment of larger scale RES based energy management systems will lead to at least some practical changes, and in many cases, a complete change from the use of fossil fuels to the use of new raw materials. This innovation requires not only new technologies, but particularly new innovative institutional frames [156–160,163,161]. The shift towards these kinds of structures, which are very different from the prevailing centralised system, will in all cases be a long-term process. Similarly to the process of acceptance and diffusion of new innovations in general, institutional lock-ins, which are reproduced by key actors, and that prevent the acceptance of new innovations, have to be 'unlocked'. For this to happen, key social actors must accept the innovation. The process must be "structured" so that laws, regulations and other institutions (social structures) support them, or at the very least do not oppose them in the first phase. New innovations must go through a technical evolution to become more developed, efficient and common solutions.

The analysis of this process below follows the structure of the Three Layer model (3L; Section 4). The special issue of the journal *Energy Policy* (issue 5, vol. 35) structured *social acceptance* in its introduction [155] as a triangle approach:

socio-political acceptance of technologies and policies, by the public, key stakeholders and policy makers;
community acceptance to specific siting decisions of RES projects by local stakeholders, residents and local authorities;
market acceptance or the process of market adoption of an innovation by consumers and investors.

In comparison with the Three Layer model (3L; Section 4), socio-political acceptance includes the Social base, consisting of the formation of general opinion, but also parts of the Supporting structures, because policy formation is already a step towards institutionalisation of collective thought. In 3L, the whole Social base belongs to the socio-political acceptance. Wüstenhagen et al. [155] also refers to "public acceptance" and "general public support", which are partly synonymous with the Social base in 3L. Therefore, "social acceptance" is something more developed and comes close to community and market acceptance. The latter ones, in turn, are weighed in connection with concrete RES projects or plans, and therefore they differ from the general level of opinion. In terms of 3L they belong to customer and market

behaviour, thus being important motives for putting the plans into practice.

Based on the innovation diffusion literature [99] it is known that along with the rising diffusion curve, capabilities and general knowledge about the given innovations improve—both as a precondition and as a result of the development. Today, the social acceptance as a whole, as structured by Wüstenhagen et al. [155] is developed both in the interface between the general opinion and supporting structures, such as the feedback system, and through customer behaviour in concrete projects.

This dichotomy can sometimes be seen in opposition to proposals for new developments, although in principle the majority of the population considers the activity as beneficial. Similar dichotomies have often been crystallised even in one person's opinions and attitudes, although typically individual motivation is different from group attitudes [162]. Often only a small but loud minority gets the most publicity, giving an impression that the opposition is larger than it really is. We must remember "*there is hardly anything in life that is universally supported*" [163]. Especially it is important to "*… recognize that the belief in the* NIMBY *theory (…) must be abandoned*" and that "*In all renewable energy acceptance cases at all levels there is only one common factor, trust*" [164].

This suggests that there are dialectics between the general level of opinion and practical acceptance that are actually inside "socio-political acceptance". According to this, the acceptance moves from the social sphere towards market behaviour as the development moves along the diffusion curve. It has also been observed that social acceptance forms a *U*-curve temporally—the initial high support decreases to its lowest point shortly before the implementation of the actual innovation, and rises again when people get more used to the project [163]. This underlines the importance of demonstrating successful examples, as "*They first need to gain the respect, understanding, and consent of citizens at large by achieving positive results*" [142].

This also means that there should be a clear distinction between the general level of acceptance and site-specific acceptance. Also Wolsink [163] notes the importance of the institutionalisation of values for a successful implementation. "*Social acceptance of RES means acceptance among all relevant actors in society-indeed much broader and conceptually fully distinguished from mere public acceptance*" [164]. This is exactly what 3L is based on in the dialectics of the social sphere and supporting structures.

Social acceptance has most commonly been discussed in the context of large RES projects, but micro-generation technologies require a different approach as homeowners and local stakeholders become a part of the energy supply infrastructure, and their acceptance can be expressed in attitudes, behaviour and most importantly investments [165]. It is also a question of how the planning and implementation processes have been realised. There has most commonly been a tendency towards top-down planning, which does not take the local population into account. As Wolsink notes "*the implementation processes of renewable energy require 'strong' ecological modernisation*", where the key approaches are, for instance, open democratic decision-making, participation and involvement, and incorporation of multiple views and ecological concerns [163].

For Europeans renewable energy is the second most important issue in energy production (average 27%) ranging from Denmark's 53% and Sweden's 51% to 12% in Lithuania and 13% in Czech Republic. The fourth most important issue is energy efficiency (2011), thus underlining the importance of SE. The other top priorities, stability of prices (29%) and especially security of energy supply (20%) [166], are also partly intertwined with SE. As Wüstenhagen et al. [155] have reviewed, "*Several indicators demonstrate that public acceptance for renewable energy technologies and policies is high in many countries*" and has been already in the early 1980s. This suggests that the social base of SE, as suggested by 3L, has been successfully passed a long time ago.

The development has enabled policies and other motives to emerge and grow. Europeans seem to be in favour of the EU coordination of energy policies (60%) above national measures, and also of solidarity between Member States in the event of supply difficulties (79%) [166]. "*The number of countries with some type of policy target and/or support policy related to renewable energy more than doubled (…) from an estimated 55 in early 2005 to 118 by early 2011*" [167]. Energy, and RES in particular, has moved to the top of the international political agenda [168], which clearly means that the institutionalisation of sustainable energy is an on-going process globally.

According to a recent review [142], until lately, the expansion of RES in practice has been very slow, being far less than, for instance, the increase of world coal production,. "*China alone increased its coal output in 2005 and 2006 by more than three times (…) the equivalent rise of world renewable output since 1990*", and global projections for coal output were even more striking [142]. Subsidies have also been smaller for RES than for any conventional fossil production. For instance in the USA nuclear energy production has the largest proportion of tax breaks (76%), coal has 12%, while RES has only 3%. In 2004 the World Bank gave out a total of US$12 billion for energy projects, of which only US$1.7 billion went into RES projects [142].

The development of industrial applications and products, new business, and integration with the mainstream energy sector of the Sustainable Energy Concept is in its very early phase. Industries who manufacture the technologies are only just about to emerge in the markets, starting with an early generation of technologies, and actually fighting against the prevailing structures instead of mutual synergy. Energy utilities do not really rely on these newcomers, as they logically strive for a maximal economic gain. Still, the RES solutions must always meet the concurrence in real time markets, where the opponents are at the opposite end of their diffusion—meaning that technologies with decades of operation and technical evolution, investments paid back a long time ago, and the social structures supporting them, all have the benefits of mass production and developed value chains etc.

In 2010, however, renewable power increased by 15.5%, biofuels by 14%, solar capacity by 73% and wind capacity by 24.6% [169]. This is a fundamental increase compared to development in earlier years and it gives very positive signals for the future.

Despite some pessimistic views [129,138] there are some indications that by 2050 the projected savings and implementation of RES technologies can realistically result in the creation of a 100% RES system in Denmark [148–150], Ireland [151], Macedonia [152], Croatia, Portugal, New Zeeland, Australia, and some towns and islands in various other countries (review and original references in [152]), or a transition to a fully sustainable global energy system [170], with all energy being produced by wind, water and solar power globally [153,154]. This development has a number of significant positive impacts, for instance in the regional and national economics, energy security and independence, reduction of greenhouse gas emission (to only 10.2% from the 2000 levels) and health costs, improved employment with new jobs, and a remarkable commercial potential. Reductions in the value chain of fossil fuels will, of course, be inevitable [148–150].

A recent historical analysis of the diffusion of coal, oil, gas and nuclear technologies showed that under favourable conditions a massive penetration of these few energy technologies has led to

market dominance [171]. For RES technologies, despite their low market shares of all energy, their expansion until now fits this historical pattern. Further, their already strong spatial diffusion worldwide could indicate a high overall potential if the growth conditions remain good. Using the average observed growth rates of the prevailing energy sources in the past, the share of RES would grow from its present 19% to 60% in 2050, representing a 27% drop in the baseline CO_2 emissions [171].

The physical prerequisites for this kind of renewal of the energy sector exist, but the question is whether there is political will and courage to boost new SE. Diffusion of these technologies depends on a number of factors, but single and separate units are emerging all the time. Along with time they will become more common and form meaningful entities. In a time frame of 20–30 years, the development may result in structural changes across the whole energy sector, as already anticipated by Peura and Hyttinen [32] in their **dichotomy** vision: There will be a division of the energy sector into two strategically different spheres—one centralised, the other distributed, which in the future will form the structure of implementation of integrated sustainable energy.

6. Conclusions

> No species has ever been able to multiply without limit. There are two biological checks (...)—a high mortality and a low fertility. (...) Man can choose which of these checks shall be applied....
>
> –Harold F. Dorn, in [9].
>
> ... even with extremely large limits on human population size, the amount of time remaining (...) is not extremely long. Within the next 150 years or so, and possibly much sooner than that, a drastic (...) decline in the global population growth rate will be inevitable (...) only by some combination of fewer births and more deaths. Hardly anybody favors more deaths.
>
> –Joel E. Cohen [9].

The above citations neatly summarise the urgent need for global change. This need has a firm theoretical basis, and it is the only valid conclusion that can be drawn from the abundant compilation of data and observations. The state of the world of course, ultimately only reflects the impact of practical actions for breaking out from the evolutionary pattern of robbery, including for instance population regulation, pollution prevention and a sustainable use of resources. There is a call for a new kind of scientific understanding. Technical reforms alone will not be enough; the anticipated renewal will most likely lead to a comprehensive societal change.

Energy plays an important role just on the edge of the interface between society and the environment, having significant economical, societal as well as environmental impacts. Gradually environmentalism and sustainability have been introduced into the conduct codes along with the traditional business thinking. In the energy sector, this ecological modernisation means a shift towards sustainable energy.

Changes in the organisational culture and the response to environmental issues can be outlined in evolutionary phases as described in the Three Layer (3L) model. This development is a social phenomenon, which is in line with cultural evolution. This is a collective manifestation of the behaviour of single actors. It can clearly be seen as an accelerating process where measures of sustainable energy are in the process of being integrated into international, national and regional policies, business strategies, and personal values. The institutionalisation of the process is the most important prerequisite for a successful implementation of sustainable energy in practice.

The establishment of sustainable energy systems on a larger scale will, in most places, require at least some practical changes, and, in many cases, a total change from fossil fuels to new raw materials and new technical solutions. The emergence of such new structures, which differ a great deal from the prevailing centralised system and also from implementing just separate RES projects, will, in all cases, be a long-term process. The process resembles the acceptance and diffusion of any new innovations which always have to overcome several thresholds or obstacles:

1. They have to attain the social acceptance and general approval. The analysis here suggests that this phase has been successfully passed.
2. They must be "structured" and institutionalised in such a way that laws, regulations and other social structures support them or do not oppose them; the evidence reviewed in this study shows that the policy level and market behaviour are in many cases, positive, but national regulations and structural opposition by a number of large energy utilities are still delaying the development.
3. They have to go through technical evolution to more advanced solutions. Technologies are still in an early developmental phase and system approaches have become more common only recently.

Even 100% RES systems are technically and physically possible, and there is a social demand for a more wide spread use of sustainable energy. In Boserupian terms, technology can develop towards taking advantage of the existing potential of RES and replacing the use of fossil fuels within the limits of their carrying capacity without undermining the ecosystem services. But in Malthusian terms, the use of energy cannot increase without depleting the sustenance base of the whole of humankind.

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